Detector for the detection of electromagnetic radiation

The invention relates to a detector for the detection of electromagnetic radiation, which detector includes at least one scintillator, at least one CMOS chip and one ceramic basic element, a respective intermediate layer being provided each time between the scintillator and the CMOS chip and between the CMOS chip and the ceramic basic element. Further aspects of the invention concern the manufacture of such a bubble-free intermediate layer and the manufacture of a detector that is provided with such an intermediate layer.

Detectors of this kind are used to convert, for example, X-rays into radiation in the visible range, for example, in X-ray examination apparatus.

Detectors for, for example, X-ray examination apparatus are customarily constructed in combination with scintillators, CMOS chips and a ceramic basic element; the light emitted by the scintillator is then detected by the photosensor device that is provided on the CMOS chip.

The uniformity of the gap width of said intermediate layer between the scintillator and the CMOS chip has a significant effect on the detection accuracy of the detector and hence on the overall image quality of the X-ray examination apparatus. Air inclusions in the intermediate layer have a negative effect on the detection accuracy of the detector.

JP 09054162 A discloses an X-ray detector in which a transparent intermediate layer that consists of a cured adhesive is provided between the region of the scintillator and the region of the photosensors.

The gap width of the intermediate layer is determined by a spacer; in particular an adhesive tape is used to enhance the uniformity of the gap width. In a preferred embodiment of the invention the region of the scintillator and the region of the photosensors are positioned so as to extend perpendicularly to one another and the adhesive is introduced from above while utilizing the capillary effect and the force of gravity, a spacer being provided at the lower end of the gap. Such positioning at right angles is very complex from a point of view of technical industrial manufacture, because manufacturing processes of this kind often are economically carried out in the horizontal plane. When an adhesive tape is provided at the lower end of the gap as described above, the capillary effect that is necessary

See Sub Spec. filed on 9/15/02

for complete introduction is partly limited so that the desired complete expulsion of air is not possible. Capillary forces can regularly be encountered only in open systems; this occurs only conditionally at the lower end of the gap in the described arrangement. The handling of the described spacer also presents a problem, that is, notably the application of an adhesive tape in an environment with dimensions in the μm range.

It is an object of the invention to realize a detector that is provided with one or more intermediate layers that achieve a high degree of uniformity of the gap width and can be manufactured in large numbers at acceptable costs. It is also an object of the invention to provide methods of manufacturing said intermediate layers and of industrially manufacturing detectors at acceptable costs while utilizing said methods.

The object is achieved in that the detector for the detection of electromagnetic radiation consists of at least one scintillator, at least one CMOS chip and one ceramic basic element, that a respective intermediate layer that is defined in respect of its gap width is arranged each time between the scintillator and the CMOS chip and between the CMOS chip and the ceramic basic element, and that said intermediate layer contains at least two adhesives (A, B) of different consistency.

The detector, being used notably as an X-ray detector or as a detector for computed tomography apparatus (CT apparatus), includes an intermediate layer that is realized notably as an adhesive. The use of an adhesive for the intermediate layers ensures that reliable bonds are obtained that are mechanically and thermally stable.

The desired defined gap width of the intermediate layer is obtained notably by the appropriate choice of the spacers. Spacers in the sense of the invention are components that serve exclusively for realizing the desired spacing, for example wires, or components that are otherwise functionally necessary and whose dimension may have been chosen especially for this purpose, for example, bumps that are present on the CMOS chip. The desired respective gap width can be simply realized by an appropriate choice of the dimensions of the spacer. Use is preferably made of a commercially available wire having a circular cross-section. Wires of this kind can be readily purchased at low costs and in standard sizes of from 15 to 75 μm in the preferred materials such as Au and AlSil. On the other hand, the bumps can be realized by means of customary methods so as to take into account the desired height, thus enabling technologically simple realization of the desired dimensional accuracy. The spacers or the bonding points for the adhesive (A) are preferably provided in areas that do not essentially influence the function of the detector, for example, in optically inactive regions on the CMOS chip. No additional surface area is required for said

placement and use of very small quantities of the adhesive (A), the main objective of the use of the adhesive (A) being achieved nevertheless. This adhesive serves for the fast fixation of the desired uniform gap width while utilizing a minimum amount of materials for this purpose.

Commercially available epoxy resin, cyanoacrylate or acrylate adhesives that can be easily applied and cured quickly can be used as the adhesive (A) for this application in accordance with the invention.

The adhesive (A1) is electrically conductive so as to enable dissipation of charges from the rear of the CMOS chip.

In order to achieve an as small as possible gap width, at least some quantities of the adhesive (A1), notably on the adhesive points, are applied directly to the rear surfaces of the CMOS chip as well as to the ceramic basic element. In that case a plurality of spacers are arranged directly between the surfaces of the CMOS chip and the ceramic basic element, that is notably without quantities of the adhesive (A1) coming into contact therewith.

Furthermore, at least some quantities of the adhesive (A2) are applied to the surface of the scintillator as well as to the bumps present on the CMOS chip.

The adhesive (B) in accordance with the invention is a low-viscosity 2-component adhesive, preferably on an epoxy resin basis, that has a refractive index > 1.5 and enables low-loss transmission of light in the wavelength range of from 450 to 550 nm. This adhesive (B), providing the major part of the adhesive force in the intermediate layer, does not age significantly under the influence of electromagnetic irradiation, that is, not even over prolonged periods of time. Suitable flow behavior is required notably so as to ensure reliable filling that is complete and free from bubbles. The curing of the adhesive (B) can be advantageously adapted to the thermal loadability of the contact partner.

The object of the invention is also achieved by means of a method of forming an intermediate layer between a CMOS chip and a ceramic basic element, where spacers and quantities of an adhesive (A1) are applied to the surface of the ceramic basic element during the first step, where the applied quantities of an adhesive (A1) project from the spacers, where subsequently the CMOS chip is placed on said quantities and is bonded and fixed while resting on the spacers and quantities of the adhesive (A1), and where during a second step the gap remaining between the CMOS chip and a ceramic basic element is completely filled with an adhesive (B) which is applied to a side of the CMOS chip in the horizontal position and enters the gap under the influence of capillary forces and is subsequently allowed to cure.

The object of the invention is also achieved by means of a method of forming an intermediate layer between a scintillator and a CMOS chip, where at least quantities of an adhesive (A2) are applied, during the first step, to the bumps that are provided in optically inactive regions of the CMOS chip surface, after which the scintillator is arranged on the bumps and is bonded and fixed while resting on the bumps and on the quantities of the adhesive (A2), and where in a second step the gap remaining between the scintillator and the CMOS chip is completely filled with an adhesive (B) which is applied to a side of the scintillator in the horizontal position and enters the gap under the influence of capillary forces and is subsequently allowed to cure.

The invention also relates to an X-ray examination apparatus which includes at least one detector for the detection of electromagnetic radiation, at least one scintillator, at least one CMOS chip and one ceramic basic element, a respective intermediate layer that is defined in respect of its gap width being applied each time between the scintillator and the CMOS chip and between the CMOS chip and the ceramic basic element, said intermediate layer containing at least two adhesives (A, B) of different consistency and spacers.

Embodiments of the invention will be described in detail hereinafter with reference to the drawing. Therein:

Fig. 1 is a diagrammatic side elevation of a part of a detector 1 with an intermediate layer 2 provided between a CMOS chip 3 and a ceramic basic element 4, and

Fig. 2 is a diagrammatic side elevation of a part of a detector 1 with an intermediate layer 2 provided between a scintillator 6 and a CMOS chip 3.

Fig. 1 shows a part of a detector 1 that is provided with an intermediate layer 2 between a CMOS chip 3 and a ceramic basic element 4 after completion of the execution of the method of manufacturing an intermediate layer of this kind. This result is achieved by means of the following steps that form part of an industrial manufacturing process.

Spacers 5 that in this case consist of Au and have a diameter of 30 µm are arranged on the surface of the ceramic basic material 4, consisting of a bondable material such as AgPt, by means of a customary standard technique. Adjacent these two wires, extending parallel to the direction of flow of the adhesive (B), four quantities of the adhesive (A1) are deposited, without contacting the wires, said adhesive in this case being a conductive 2-component epoxy resin adhesive that cures comparatively quickly, said deposition being performed by means of a commercially available dispenser. The quantities of the adhesive (A1) are droplets that project approximately 40 μm from the surface of the ceramic basic element 4. The CMOS chip 3 is moved to the desired, accurately defined

position over the ceramic basic element 4 so as to be positioned horizontally by means of a semi-automatic positioning device that notably utilizes customary measuring and positioning means and data techniques.

After the positioning, where the CMOS chip 3 first contacts the surface of the droplets of the adhesive (A1), the CMOS chip 3 will bear on the spacers 5 only under the influence of the force of gravity. The droplets of the adhesive (A1), then being in contact with the ceramic basic element 4 as well as with the CMOS chip 3, are cured in this position.

After the curing, preferably under the influence of heat as can take place in a Flip Chip Bonder, the desired and accurately defined gap with a gap width of approximately 30 μm will have been realized in a mechanically stable manner.

Subsequently, the adhesive (B) is introduced laterally and without bubbles into the gap by means of a dispenser, that is, from one side of the CMOS chip 3 only; the entire assembly, that is, notably the components of the intermediate layer 2 of the CMOS chip 3 and the ceramic basic element 4 has been heated to 80 °C in advance. The adhesive (B), whose viscosity is adapted to the required flow behavior, completely fills the gap (without air inclusions) under the influence of capillary forces. The adhesive (B) forms a respective meniscus at the other three openings of the gap, but does not emanate therefrom itself. Because of their small dimensions, the cured droplets of the adhesive (A1) that are present in the gap and the spacers do not have a significant effect on the flow behavior and on the formation of air inclusions. After the curing of the adhesive (B) while applying small amounts of heat, that is, 60 °C for approximately 2.5 hours, there will be obtained a stable intermediate layer 2 that ensures the necessary long-term stability.

Fig. 2 shows a part of a detector 1 that includes an intermediate layer 2 that is present between a CMOS chip 3 and a scintillator 6 after completion of the execution of the method for forming an intermediate layer 2 of this kind. This result is obtained by means of the following steps that form part of an industrial manufacturing process.

In optically inactive regions on the CMOS chip 3 there are provided spacers 5 that have a height of approximately 30 μm; they are referred to as bumps and in this case are made of NiAu. Using customary techniques, these bumps are accurately proportioned in respect of height so as to achieve the desired height of the gap of the intermediate layer 2. Droplets of the adhesive (A2) are applied only to the tips of individual bumps that regularly occupy a surface area of approximately 40 x 40 μm. The adhesive (A) is a comparatively fast curing adhesive that can be readily deposited by means of commercially available dispensers. The scintillator 6 is moved to the desired accurately defined position over the CMOS chip 3

so as to be positioned horizontally by means of a semi-automatic positioning device. After the positioning, where the scintillator 6 first contacts the surface of the droplets of the adhesive (A2), the scintillator 6 will bear horizontally on the spacers 5, that is, exclusively under the influence of gravity. The droplets of the adhesive (A2), then being in contact with the scintillator 6 as well as with the bumps, are cured in this position. After the curing, preferably under the influence of heat as can take place in the bonder, the desired and accurately defined gap with a gap width of approximately 30 μm will have been realized in a mechanically stable manner. Subsequently, the adhesive (B) is introduced laterally and without air bubbles into the gap by means of a dispenser, that is, from one side of the CMOS chip 3 only. The adhesive (B), whose viscosity is adapted to the required flow behavior, completely fills the gap (without air inclusions) under the influence of capillary forces. The adhesive (B) forms a respective meniscus at the other three sides of the gap, but does not emanate therefrom itself. Because of their small dimensions, the spacers 5 that are present in the gap do not have a significant effect on the flow behavior and on the formation of air inclusions. In the case of gap heights amounting to less than 50 µm, spacers 5 or cured quantities of the adhesive (A2) that occupy a surface area of more than 100 x 100 μm cannot be circumvented without giving rise to the risk of undesirable formation of air inclusions. After the curing of the adhesive (B) while applying small amounts of heat, that is, 60 °C for approximately 2.5 hours, there will be obtained a stable intermediate layer 2 that ensures the necessary long-term stability.